WDFW HABITAT GUIDELINES

1 HEADING PLACEHOLDER – DO NOT DELETE

2 HEADING PLACEHOLDER – DO NOT DELETE

3 HEADING PLACEHOLDER – DO NOT DELETE

4 SELECTING A RESTORATION APPROACH

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4.4 Approaches to Solving Common Restoration Objectives

All stream channels and associated biota are dynamic by nature, responding to their supply of water, sediment, nutrients, pollutants, organics, light, and heat. Changes in the magnitude, nature, or frequency of these inputs, or changes to the stream itself, create a disturbance in the physical and/or chemical environment and often lead to a biological response (Pickett and White 1985). Such changes may be gradual or abrupt, natural or anthropogenic (the result of human activities).

Following are examples of what might be done to achieve common stream habitat restoration objectives including:

- Restoring Natural Sediment Supply
- Restoring Stream Hydrology
- Restoring Habitat Connectivity
- Restoring Water Quality
- Restoring the Supply of Organic Material
- Restoring Habitat Complexity
- Restoring a Degraded/Degrading Stream
- Restoring an Aggraded/Aggrading Stream
- Restoring Salmonid Spawning Habitat
- Restoring Salmonid Rearing Habitat

The focus of the discussion is on addressing anthropogenic causes of stream and habitat degradation. Potential causes of degradation that are identified in the text are not exhaustive but are meant to provide the reader with a sense of the variety and types of problems that may need to be addressed. It is also intended to reinforce the need to conduct a site, reach, and/or watershed assessment before proceeding to restoration design.

Many of the techniques that are listed work to restore disrupted processes in the landscape to provide long-lasting benefits while others provide immediate but short-term benefits. Some provide more predictable results than others. These techniques are broad suggestions offered as guidance and are not intended to limit the designer. Actual designs may include a combination of techniques in order to fully address restoration objectives. Details of specific techniques are described in Chapter 5. Long-term stream habitat restoration requires that techniques be employed to address the root cause of the problem, rather than to merely treat the symptoms.

4.4.1 Restoring Natural Sediment Supply

Sediment is the product of erosion and may be derived from within a stream channel (e.g., bed and bank erosion, debris flows) and from sources outside the channel (e.g., surface erosion and mass wasting). Surface erosion occurs when soil particles are detached by wind, rain, overland flow, freeze-thaw, or other disturbances (animals, machinery). Mass wasting (slumps, landslides, debris avalanches, and soil creep) result from weathering, freeze-thaw, soil saturation, groundwater flow, wind stress transferred to soil by trees, earthquakes, and undercutting of streambanks. According to a literature search by Spence et al (1995), the supply and composition of sediment delivered to a stream is dependent upon climate (determines the timing, amount, intensity, and type of precipitation), topography (determines slope steepness, length, elevation, and aspect), soil type (determines soil texture and erodibility), soil saturation, surface cover and organic matter content of the soil (determines resistance to soil detachment and transport), soil depth and degree of weathering, and the degree of upslope disturbance (Swanston 1991, Beschta et al 1994, Reiter et al. 1994). As a result of these factors, sediment supply delivered to a stream varies over both space and time (Benda et al 1998).

Once sediment enters the stream, it is subject to transport and deposition by flowing water. The sediment transport capacity of a stream is related to channel hydraulics and geometry. Moving water exerts a force on the bed and banks of the channel. That force, referred to as shear stress, is available to move sediment grains downstream. Since the shear stress required to initiate and maintain transport increases with the size of the sediment, smaller particles tend to move more easily and travel longer distances than larger particles (Beschta 1987). Shear stress is proportional to the depth of the water and the slope of the channel. Water depth is a function of the magnitude of flow and channel geometry.

The sediment load transported by stream flow is comprised of a suspended load and a bedload. The suspended load refers to sediment that is carried and supported by the flow. It generally consists of relatively fine material (clay and silt sized particles). Bedload consists of larger particles that are pushed along by the flow but are supported by contact with the bed of the stream. Suspended sediment plays a significant role in water quality and affects the ability of fish to live in the stream. Bedload transport dominates channel morphology; it determines the nature of the bed material and provides a source for its renewal. (Ontario Ministry of Natural Resources 1994)

Sediment size, volume, and transport dynamics exert a major control on channel form, which describes the pattern, cross-section, and profile of the stream as well as its internal relief (bed form). Channel form controls the physical state of the stream (e.g., temperature, depth, substrate, and velocity) that collectively influence the abundance and diversity of aquatic life (Naiman 1998). The size and sorting of bed material are critical to habitat. Coarse bed materials (e.g., gravel, cobble, boulders) have a higher porosity than fine sediments (e.g., sand, silt, clay); likewise, well-sorted material has a higher porosity than material that is poorly sorted. Higher porosities allow for higher rates of interstitial flow (Edwards 1998) and yield greater amounts of interstitial habitat. Such habitat is critical to macroinvertebrates, most of which spend the majority of their lives attached to bed material (Hershey and Lamberti 1998), as well as to fish and wildlife that feed on macroinvertebrates and that spawn and/or rear in the bed. The preferred substrate composition varies among species. Finer material are often critical to formation of floodplain, estuarine and marine channels, beaches and habitats.

Changes in sediment volume can affect the stability of a channel, causing channel aggradation if the volume delivered exceeds the available sediment transport capacity, and causing channel degradation if the volume is insufficient (Miller et al. 2001). Sediment deposition in floodplains is a source of nutrients, silt, and organic material (Leopold 1994, National Research Council 1992).

Sediment supply is also a critical element of marine and lacustrine habitats. The focus of this guideline is riverine habitats. It is hard to separate estuarine habitats from river processes so they are mentioned here but a future guideline will focus on marine and estuarine habitat restoration.

4.4.1.1 Activities that Impact Sediment Supply

The sediment supply to the stream varies naturally over time due to climatic variability and periodic natural events such as wildfire (Swanton 1971) and volcanic eruptions (Rees 1981). Anthropogenic influences, stemming from land use and stream alterations, can significantly alter the frequency and magnitude of sediment supply to the stream and, thus, severely impact the stream and aquatic habitat (discussed in Chapter 2). Human activities that impact the amount and type of sediment available to a particular stream reach include those that affect the sediment supply from the watershed and those that affect the sediment supply and transport from upstream reaches and tributaries of the stream reach. These include, but are not limited to:

Direct Causes:

- Direct dumping of material in the stream
- Removal of material from the stream (e.g., in-stream gravel mining or dredging operations) thus reducing the gravel supply to downstream reaches (Collins and Dunne, 1990; Kondolf and

Swanson, 1993) and removing the natural armor from the affected streambed by exposing finer underlying material to flow.

Indirect Causes:

- Land-use practices that, through alteration of soil structure, vegetation, topography, and hydrology, significantly increase the delivery of fine and coarse sediments to streams. Such increases may be chronic, via accelerated rates of surface erosion, and/or abrupt, via mass wasting events (e.g., landslides, debris torrents). These activities include road construction, maintenance, and use, livestock grazing, placer mining, urbanization, agriculture, timber harvest and general land clearing (Smith, 1939; Klingeman, 1981; Collins and Dunne, 1990). Sediment generated from erosion associated with land-use activities is often predominately fine material (Klingeman 1981).
- Riparian zone management practices leading to the removal or alteration of riparian vegetation. Vegetated riparian zones trap sediment contained in surface runoff and floodwater and provide streambank resistance to the erosive forces of flowing water (Ontario Ministry of Natural Resources 1994). Loss of riparian vegetation may increase the supply of sediment to the stream via surface runoff and accelerated rates of bank erosion.
- In-stream activities, such as operation of equipment and vehicles within a stream channel, yarding of logs through a channel, and foot traffic by livestock, people and pets, stir up sediment in the vicinity of the activity, increasing its availability for downstream transport.
- Activities that directly or indirectly alter floodplain-stream interactions. Floodplains often serve as a natural storage areas for suspended sediment during high stream flows. If a floodplain is disconnected from the stream or vegetation is removed, sediment that would have been stored there is transported further downstream.
- Channel modifications that alter the sediment transport capacity of the stream and thus the sediment supply to the downstream channel. Such activities may include dredging, widening, narrowing, steepening, flattening or straightening the channel, levee construction, the removal of wood and other roughness features. It also includes either the installation or removal of undersized culverts or other constrictions to flow that either store sediment or release stored sediment. These activities alter the water depth and velocity, channel slope, and, thus, the stability and sediment size distribution of the channel bed. Increases in the sediment transport capacity of a reach may increase bed and bank erosion in the affected and upstream channel reaches, resulting in an increased supply of sediment downstream. Decreases in the sediment transport capacity of a reach may cause aggradation in the affected and upstream channel reaches, resulting in a decreased supply of sediment downstream.
- Stream bank protection and armoring that reduce the amount of sediment, including gravels, recruited to the stream (Klingeman, 1981).
- Channel obstructions and constrictions that intercept downstream sediment transport. Such modifications include dams (including road crossing with undersized culverts) that trap sediment in their upstream reservoirs, reducing the supply of gravel to downstream reaches (Buer et al, 1984)

- Land use change and flow management practices within the watershed that alter stream hydrology, thereby altering the sediment transport capacity of the stream. Altered hydrology may also alter the level of the surrounding water table, adversely impacting the riparian vegetation. Loss of riparian vegetation may increase the supply of sediment to the stream via surface runoff and accelerated rates of bank erosion. Land uses and flow management practices that may alter stream hydrology are discussed under "Restore Stream Hydrology".

4.4.1.2 Techniques to Restore Sediment Supply

The most effective long-term solution to restoring stream sediment supply must address the cause of altered supply, not just the symptom. Most causes of altered sediment supply are indirect in nature and many derive from non-point sources. As a result, restoration will likely need to occur upstream of the affect stream reach and/or outside the channel. Appropriate techniques used to restore the natural sediment supply to the channel may include:

- To restore natural sediment supply that has been lost—
    - Stop or curtail in-stream dredging and gravel mining operations
    - Remove or modify existing bank protection. This may require land use modification (see *Sediment Control* and *Land Preservation and Buyback* techniques).
    - Restore sediment transport by removal of upstream dams. Management of sediment stored in dam reservoirs is a key element of the design.
    - Artificially place bed material in discrete locations or implement a periodic or continuous gravel supplementation/feeding plan (see *Spawning Gravel* technique). These techniques will provide only short-term benefits or in fact, may be detrimental, unless repeated or continuous supplementation is made. They do not address the source of the problem, only the symptom.
- To reduce the excessive supply of sediment to the stream—
    - Stop or curtail sediment dumping in stream
    - Prevent or minimize direct access livestock, foot traffic, and vehicle across the channel
    - Implement upland best management practices for existing land use activities within the watershed and/or modify the land use in order to increase upland stability and to reduce surface erosion and mass wasting events (see *Sediment Control, Land Preservation and Buy-back* techniques)
    - Restore natural stream hydrology (see Restoring Natural Stream Hydrology)
    - Restore the sediment transport capacity of upstream channel that has been disturbed (see *Channel Modification* techniques)
    - Restore natural sediment detention upstream (e.g., restore natural roughness and riparian vegetation) (see *Structures to Create and Maintain Natural Channel Bedform and Habitat Diversity* and *Riparian Management* techniques)
    - Restore or increase longitudinal and horizontal extent of a vegetated riparian zone to increase the detention of sediment from surface runoff and floodwater and increase

bank stability (see *Riparian Management* technique)

- Restore stream access to its floodplain to increase storage of suspended sediment *(see Channel Modification, Levee Removal and Setback, Land Preservation and Buy Back techniques)*
- Install bank protection. Note that this technique is an acceptable habitat restoration technique under only limited conditions. (see *Sediment Control* technique)
- Install in-stream sediment detention basins. This technique will provide only short-term benefits, if any, unless repeated application is made. It does not address the source of the problem, only the symptom. (see *Sediment Control* technique)

4.4.2 Restoring Stream Hydrology

With few exceptions (spring-fed streams, drainage from extensive wetlands), flow is highly variable in streams during the course of a year, although the seasonal timing of high flows and low flows may be quite predictable (National Research Council 1992). The variability of stream flow affects the overall health of aquatic systems and stream functions in many ways. It is necessary for the distribution of sediment and the basic character of the channel. It is critical to the survival of aquatic life and provides them access to habitat and food. Stream flow sends signals to fish and other aquatic life that use flow as a cue for breeding or other features in their life cycle. Stream flow is also an important aspect of water quality and influences the water level of nearby groundwater and surface water bodies such as wetlands, lakes, and ponds.

Flow is a major factor in determining the water depth in a stream which affects the stream's capacity to scour and transport sediment. Most reworking of stream channels occurs when the discharge is near bankfull (Leopold 1994). Bankfull discharge occurs during relatively frequent events at an average recurrence interval of approximately 1.5 years. This regular disturbance is important in forming and maintaining the existing channel and existing habitat within the channel. Higher flows carry more sediment but they are so infrequent that they do not accomplish as much work as the more frequent events.

Flows dictate the frequency, extent, and duration of a stream's interaction with its floodplain which, in turn, influences the vegetation and wildlife that reside there. Floodplains may serve as a source or sink of nutrients, water, sediment, vegetation propagules, and organic material (including large woody material) to the stream (Swanson and Sparks 1990). In a literature search conducted by Miller et al. (2001), it was noted that high flows rejuvenate biological communities in the following ways:

> "High flows mobilize sediment on the channel bed, banks, and floodplain, thus inducing channel migration, bar formation, floodplain scouring, and the formation of secondary channels that may be critical for aquatic species. These processes increase channel complexity for fish, and create new substrate for riparian vegetation colonization – both of which are critical for maintaining the long-term health of these species. In fact, the

composition and relative abundance of species in a river system is often closely related to the magnitude and frequency of high flows (Schlosser 1985)."

Hyporheic zone is …

4.4.2.1 Activities that Impact Natural Stream Hydrology

Native fish and wildlife have adapted to, and in many aspects, are dependent on natural stream hydrology. Land use and water management activities alter the magnitude, timing, and duration of flow in many streams. The most common causes of altered stream hydrology include:

Direct causes

- Controlled releases from dams that optimize the availability of water for power production, irrigation, water supply, recreation, and flood control.
- Water withdrawals from the stream and aquifer for power production, irrigation, and water supply.

Indirect Causes

- Loss of water retention and acceleration of runoff in the watershed. Loss of retention combined with accelerated runoff typically raises the magnitude of flood peaks and reduces the availability of water to streams during low flow season (baseflow conditions). Loss of water retention acceleration of runoff may be caused by:
    - Altered land cover (e.g., removal of native vegetation, increased impervious surface area) due to development, road construction, timber harvest, and agriculture.
    - Old stormwater management practices that focus on getting water off the land and into the streams as quickly as possible to reduce flooding.
    - Loss of floodplains/isolation of streams from their floodplains due to levee construction, floodplain fill, channelization activities, and stream degradation. These activities reduce floodplain storage of high flows, thereby increasing flow within and downstream of the affected reach.
- Hyporheic zone is affected by levees, distribution of water diverted for irrigation, …

The physical, biologic, and chemical effects of altered stream flow are described in Chapter 2.

4.4.2.2 Techniques to Restore Stream Hydrology

Restoration of the flow regime is one of the most neglected aspects of stream and river restoration (National Research Council 1992) despite how critical it is to maintaining and/or restoring the stream channel and the ecosystem that it supports. In highly urbanized areas and in stream reaches with water regulated by active dams, it may be impossible to restore stream hydrology to pre-disturbance conditions. However, strategies can be employed to reduce the impacts of existing infrastructure and to minimize or eliminate the impacts of future development.

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With the exception of flow regulation of dams, alterations in stream hydrology are the result of cumulative impacts to the watershed. Therefore, restoration of stream hydrology generally requires a watershed-scale land restoration and management strategy.

- Techniques to Increase Base Flow—
  - Remove dam or modify dam impoundment/release management (see *Flow Management* technique)
  - Reduce water withdrawal/diversion
    - Reduce water consumption through widespread domestic, industrial, municipal, and agricultural water conservation (e.g., more efficient irrigation practices, use of native and drought-tolerant vegetation…)
      - By alternative land use that requires less water (e.g., by planting drought tolerant crops, using drought-tolerant/low water landscaping alternatives [including native plants], reducing the size of traditional high water need crops and landscapes)
      - By decreasing energy demands (WA is primarily dependent upon hydroelectric power) and using alternative energy sources
      - By employing methods that improve water retention of the soil (organics, mulch),
      - By using more efficient irrigation systems and irrigation practices, more efficient fixtures and appliances
    - Improve efficiency of water delivery systems (e.g., fixing leaks and using systems that minimize loss of water to evaporation and infiltration)
  - Increase stormwater retention and groundwater recharge
    - Stormwater management
    - Reducing the amount of impervious surface in the watershed
      - Land use practices and regulations that minimize the allowable percent of impervious surface in the watershed
      - Road decommissioning
    - Restore stream access to floodplains (see *Channel Modification*, *Levee Removal and Setback*, *Land Preservation and Buy Back* techniques)
    - Revegetating denuded areas within the watershed
    - Protecting wetlands and other infiltration areas
- Techniques to Reduce Peak Flow Magnitude—
  - Increase stormwater retention and groundwater recharge (as outlined above)
- Techniques to Restore the Natural Pattern of High and Low Flows—
  - Remove dam or modify dam impoundment/release management (see *Flow Management* technique)
  - Reduce water withdrawal/diversion (as outlined above)

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4.4.3 Restoring Habitat Connectivity

Habitat requirements vary among aquatic species and among life stages of individual species. In addition, seasonal use of different habitats is common among many fish and wildlife species. Therefore, connectivity between habitats is critical to aquatic organisms. Connectivity is the ability of organisms, materials, and energy to move freely within the landscape (Peck 1998—p 9 of culvert manual); upstream, downstream, and laterally onto and off the floodplain and side channels. Barriers to the movement of organisms are typically classified as complete, temporal, or partial. Temporal barriers block the movement of the entire population of an organism some of the time; partial barriers block only the smaller or weaker individuals of a population all of the time, limiting the genetic diversity that is essential to support a robust population (Bates 2002—culvert manual).

Roni et al (2002) identifies three basic types of habitats that are commonly isolated from the main stream channel:

1) Off-channel freshwater areas such as sloughs, alcoves, wall-based channels, ponds, wetlands, and other permanently or seasonally flooded areas. These areas are important rearing areas for juvenile salmon. Discuss importance to other fish and wildlife. Estimates of % lost Use Skagit study as example of % loss
2) Stream reaches isolated by culverts, dams, and other artificial obstructions. Loss of entire stream reaches is critical to species whose survival depends upon their ability to migrate through the lost reach in order to find suitable habitat and food, and to species whose survival depend on those migrating species. Johnson et al (2001) report that, as of March 2001, a total of 1,963 WA State Department of Transportation road crossing of fish bearing streams have been documented; 40% are barriers to passage of adult salmonids. It is estimated that there are a total of 33,000 salmonid passage blockages in the state of Washington at this time (Paul Sekulich, WDFW, personal communication 4-12-02). The number of blockages is likely to be higher if other migratory fish and wildlife species are considered.
3) Estuarine habitat. Estuaries are important foraging areas for juvenile fish, as well as physiological transition zones for adult and juvenile anadromous fish (Healey 1982; Simenstad et al 1982). Discuss importance to other fish and wildlife. Simonstad and Thom (1992) estimated that 71% of the estuarine habitat has been lost in Puget Sound and 42% in the coastal Pacific Northwest.

4.4.3.1 Activities that Impact Habitat Connectivity

The causes of habitat isolation vary with the type of habitat. They include:

1. **Off-channel freshwater areas**

   Direct causes

   - Levee construction
   - Floodplain fill

  - Roads that parallel a stream may create a barrier to the movement of nutrients from the channel to the floodplain by hindering animals that drag carcasses from the channel.

  Indirect causes

  - In-stream and watershed activities that contribute to stream degradation, physically isolating the stream from its floodplain and lowering the water level of nearby groundwater and surface water bodies. Side channels may become dewatered or inaccessible.
  - Disturbance of natural stream hydrology so that water is no longer present in a floodplain habitat or is insufficient to sustain the habitat and/or the connection to it.

- **Stream reaches**

  Direct causes

  - Culverts, dams, or other artificial obstructions that create height, velocity, turbulence, or depth barriers to upstream fish and/or wildlife passage. Outfall drops may also create a barrier to safe downstream fish and/or wildlife passage.
  - Artificial smooth channel linings that create velocity or depth barriers to upstream fish and/or wildlife passage
  - Channel widening that creates depth barriers to upstream fish and/or wildlife passage
  - In-stream dredging that lowered the stream elevation, physically isolating the stream from its tributaries and upstream reaches
  - Structures or channel modifications that constrict the channel and prevent the downstream movement of sediment, debris and/or channel processes such as channel or meander migration

  Indirect causes

  - In-stream and/or watershed activities and that caused the stream to vertically degrade, physically isolating the stream from its tributaries and upstream reaches
  - Watershed activities leading to debris and land slides that block the channel (Whyte et al 1997)

- **Estuaries**

  Direct causes

  - Tide gates
  - Levee construction
  - Estuary fill
  - Levees, tide gates, and estuary fill may create direct blockages of organisms, material or energy or may indirectly affect organisms by reducing inflow and outflow of tidal prism necessary for movement of sediment, organisms, and water mixing to maintain temperature, nutrients and temperature characteristics and associated vegetation and food production of an estuary.
  - Dredging

  Indirect causes

  - In-stream and watershed activities that contribute to estuary aggradation or degradation resulting in the loss of that estuary or its functions.

4.4.3.2 Techniques to Restore Habitat Connectivity

The technique or techniques used to restore habitat connectivity depend upon the type of habitat that has been lost, why is was lost, and whether the processes necessary to create and maintain that habitat and its connection are present or need to be restored. There are three different levels of restoration that may be needed to restore habitat connectivity.

1) If a habitat is isolated from the main channel or adjacent reach by a direct cause, such as a man-made obstruction (e.g., a levee or culvert) or channel dredging, then restoration needs only to address that direct cause of habitat isolation. Such techniques may include:

- Remove impassable culverts or replace them with non-barrier alternatives (see *Fish Passage* technique)
- Remove/modify dams
- Remove/modify levees (see *Levee Removal and Setback, Land Preservation and Buy Back* techniques)
- Remove floodplain, estuary, or other fill (including bank protection) that isolates the habitat
- Stop dredging the channel and allow the channel to naturally rise to its pre-disturbance elevation (or artificially raise the channel to it's pre-disturbance elevation). Note that if the dredging was in response to recent channel aggradation, the cause of aggradation and its affect on the ecosystem will need to be assessed.

Note that any work done to reconnect floodplain habitat will need to be coupled with a change in floodplain management practices.

2) If a habitat exists and is isolated from the main channel or adjacent reach by an indirect cause, it is likely that the processes that naturally create and maintain the lost habitat and/or the connection to that habitat have been disturbed. Restoration of habitat connectivity will require restoration of the natural processes capable of sustaining the connection.

- Restore vertical stability to a degraded channel by addressing the cause of the degradation and raise the channel back up to its pre-disturbance elevation (see *Channel Modification* techniques)
- Restore vertical stability to a degraded channel by addressing the cause of the degradation, leave the channel at its degraded elevation, and restore salvageable habitat connections.
- Restore the natural stream hydrology (see Restoring Stream Hydrology)

3) If the isolated habitat no longer exists due to anthropogenic causes (e.g., the side channel was filled for a different land use), natural regeneration of the lost habitat may take years or decades to occur, even if the natural processes to create and maintain the habitat are intact. The designer may choose to accelerate the process by reconstructing the lost habitat. Note that creation of the lost habitat without

ensuring that the natural processes that form and maintain the habitat are intact will likely provide only short-term benefits without constant, long-term maintenance. A habitat may no longer exist also because a main channel is fixed in its location and therefore prevented from creating new habitats as it migrates across the floodplain. …

- Create Side Channel (see *Side Channel Habitat* technique)
- Create off-channel wetlands
- Create off-channel ponds

Note that abandoned gravel pits in the floodplain may offer a benefit to some species if they are connected to the main channel.

4.4.4 Restoring Water Quality

Water quality is a critical factor to the existence, abundance, and diversity of aquatic life in a stream. Temperature, turbidity, dissolved gases, nutrients, heavy metals, inorganic and organic chemicals, and pH all influence water quality. If the magnitude or concentration of any of these factors exceeds the natural range for a specific location and time of year, biological processes may be altered or impaired (Spence et al 1995).

Pollution can have direct or indirect effects on a species (Cowx and Welcomme 1998). Direct effects derive from the toxicity of a chemical; an organism may suffer acute or chronic effects depending upon the concentration of the chemical concerned, the condition of the organism at the time of exposure, and other factors such as water temperature, turbulence, and the presence of other substances (Stumm and Morgan 1981). Substances that are acutely toxic cause death or severe damage to an organism by poisoning during a brief exposure period (≤days). Substances that are chronically toxic cause death or damage to an organism by poisoning during prolonged exposure. Indirect effects of pollution result in changing water quality parameters and consequently the suitability of the habitat for the organism. Water quality standards for surface waters of the state of Washington are provided by the Washington Administrative Code (WAC) Chapter 173-201A.

Table 4.4.1. Water quality standards for surface waters of the state of Washington.

Water Quality Parameter	**Class AA Waters [a] (Extraordinary)**	**Class A Waters [a] (Excellent)**	**Class B Waters [a] (Good)**	**Class C Waters [a] (Fair)**
Fecal Coliform Organisms	Geometric mean = 50 colonies/100ml	Geometric mean = 100 colonies/100ml	Geometric mean = 200 colonies/100ml	Geometric mean = 200 colonies/100ml
Dissolved Oxygen	>9.5	>8.0	>6.5	>4.0

Total Dissolved Gas	≤110% saturation	≤110% saturation	≤110% saturation	≤110% saturation
Temperature	≤16.0°C	≤18.0°C	≤21.0°C	≤22.0°C
PH	6.5 to 8.5	6.5 to 8.5	6.5 to 8.5	6.5 to 9.0
Turbidity	≤5 NTU over background	≤5 NTU over background	≤10 NTU over background	≤10 NTU over background
Toxic radioactive, or deleterious material	Concentrations shall be below those which have the potential either singularly or cumulatively to adversely affect characteristic water sues, cause acute or chronic conditions to the most sensitive biota dependent upon those waters, or adversely affect public health.			

[a] Classes of surface water are established based upon the characteristic use of the water body. See WAC173-201A-030 and WAC173-201A-130 for details.

Source: WAC173-201A

Note that water quality standards are intended to protect essential and significant life in water, the direct users of water, and life that is dependent on life in water for its existence. They do not offer the same degree of safety for survival and propagation at all times to all organisms within a given ecosystem. (U.S. EPA 1976)

Include carcass supplementation.

4.4.4.1 Activities that Impact Water Quality

The water quality of a stream can be affected by both point and non-point sources of pollution. Point sources are those that can be traced back to a discrete discharge, such as those of industrial and domestic effluents. Non-point pollution stems from diffuse inputs from the air, groundwater, and surface water runoff. Examples of non-point source pollution include nutrients, suspended sediments, and toxins from agriculture, urban stormwater runoff, runoff from deforested areas and construction sites, mining, septic systems, and precipitation.

4.4.4.2 Techniques to Restore and Improve Water Quality

If there is an identified water quality problem in a stream, water quality restoration should be considered a priority. In general, it is of little use to develop plans for restoration, rehabilitation, or enhancement of the form of the ecosystem if the quality of water is inadequate to sustain life. (Cowx and Welcomme 1998, p 201)

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Pollution caused by point source discharges of wastewater and stormwater to air, surface water, and groundwater from industrial and municipal sites is largely controlled through National Pollutant Discharge Elimination System (NPDES) and statewide discharge permits and is outside the scope of this guideline.

Non-point source pollution, by definition, is derived from diffuse sources spread throughout a watershed. As such, restoration of stream water quality caused by non-point source pollution requires a watershed-scale land restoration and management strategy. The specific technique employed depends on the specific water quality parameter that has been identified as impaired, the identified cause of its impairment, the pollutant pathway for delivery to the stream (e.g., is it airborne, attached to sediment, or in solution?), and the form in which the pollutant is transported to the stream.

Approaches to improve stream water quality may focus on:

- Controlling the source of a pollutant. This involves reducing the amount of pollutant available for transport to the stream (e.g., avoiding excessive rates of fertilizer and pesticide application, employing best management practices to minimize surface runoff and soil erosion from the land).
- Controlling a pollutant's delivery to the stream. This involves trapping the pollutant before it reaches the stream (e.g., through the establishment of vegetated buffers between the source of the pollutant and the stream).
- Removal of the pollutant once it has reached the stream. This approach is a short-term enhancement technique that treats the symptoms of the problem rather than the problem itself. As a stand-alone treatment approach, it will require repeat application. It is generally less cost effective and more disruptive to the ecosystem than the other approaches.

Include common techniques used to restore or improve stream water quality under each approach.

4.4.5 Restoring the Supply of Large and Small Woody Material (address supply and stability) --- **Not Available at This Time**

4.4.6 Restoring habitat complexity (including cover) --- **Not Available at This Time**

4.4.7 Restoring a degraded/degrading stream --- **Not Available at This Time**

4.4.8 Restoring an aggraded/aggrading stream --- **Not Available at This Time**

4.4.9 Restoring Salmonid Spawning Habitat

The presence of adequate high quality spawning habitat is one of the keys to preserving natural spawning salmonid populations in our streams and rivers. Spawning habitat requirements vary slightly for each species but in general all salmonids need stable, relatively clean and appropriately sized gravels that are supplied with adequate amounts of clean, cold, oxygen rich water. Salmonid reproductive efficacy (fry per female) can be increased by restoring or creating these conditions.

According to a literature review conducted by Shuett-Hames and Pleus (1996), favorable spawning sites often form upstream of obstructions to flow, such as bedrock outcrops, boulders, and large woody material (Mosley 1981), and in the tail-outs of scour pools (Sedell 1984). These scour pools may be associated with structures (including large woody material and boulders) in the stream or with stream meanders. The relative importance of these two features in spawning habitat development depends on the morphology of the stream. Low gradient channels with a meandering pool/riffle morphology often have abundant deposits of gravel in pool tailouts, riffles, and point bars. Whereas in steeper channels, spawning habitat is often limited to small patches of coarse gravel associated with obstructions (Keller and Swanson 1979, Kondolf et al. 1991). Characteristics used by salmonids to select spawning sites include substrate size, water velocity, water depth, bed compaction, gravel permeability, suitable surface and sub-surface flow conditions, dissolved oxygen, water temperature, and proximity to cover and habitat utilized by emerging fry (Burner, 1951, Briggs 1953, Chambers et al 1955, Vaux 1962, Hoopes 1972, Hunter 1973, Beschta and Platts 1986, Heard 1991, Kondolf and Woman 1993, Leman 1993).

4.4.9.1 Activities that Impact Spawning Habitat Quality, Quantity, and Availability

Spawning habitat may have been lost or degraded for a number of reasons, both natural and anthropogenic. Anthropogenic impacts to salmonid spawning habitat availability include:

Direct Causes:

- Activities that replace stream reaches with artificial surfaces (e.g., culverts, concrete lined channels), not suitable for spawning (Bates 2001)
- Activities that isolate spawning habitat thus reducing the overall amount of spawning habitat available to fish (see Restoring Habitat Connectivity).
- Channel modifications, such as channelization, that shorten a stream thus reducing the overall amount of spawning habitat available to fish.
- In-stream activities, such as operation of equipment and vehicles within a stream channel, yarding of logs through a channel, and foot traffic by livestock, people and pets, that take place at or near spawning beds can cause compaction and vibration of the beds and can smother the beds with fine material, reducing interstitial flow. All of these impacts can significantly reduce the survival of eggs in the gravel.

Indirect Causes:

- Activities that alter the type and amount of sediment delivered to streams (see Restoring Sediment Supply).
- Land use change and flow management practices within the watershed that alter the stream hydrology (see Restoring Stream Hydrology).
- Manmade structures such as dams and road crossings with undersized culverts that create large scale backwatered conditions unsuitable for salmonid spawning upstream (however, they may

be suitable for rearing).

- Undersized culverts or other obstructions to flow that produce relatively high velocity jets that scour downstream reaches (Bates 2001)
- Watershed modifications that degrade water quality creating unsuitable conditions for salmonids and other aquatic life (see Restoring Water Quality).
- Activities that reduce the amount of cover available to fish including wood, boulder, and riparian vegetation removal.
- Removal of natural obstructions to flow and alteration of natural channel morphology both of which encourage formation and maintenance of suitable spawning habitat.
- Alteration of vegetation in the riparian zone which reduces the supply of large woody material to the stream. See Restoring the Supply of Large and Small Woody Material.

4.4.9.2 Techniques to Restore, Enhance, and Create Spawning Habitat

Due to the many possible causes of salmonid spawning habitat degradation, no single technique is applicable to every situation. The most long-term effective solution must address the cause of salmonid habitat degradation, and not simply address the symptom. For instance, if suitably-sized spawning gravel is lacking from a reach because the channel has been narrowed, deepened, and made steeper such that the resulting increased velocities do not allow spawning sized material to collect and remain stable in the reach, artificial placement of spawning sized gravel in the reach may lure salmonids to spawn there only to have their eggs and the gravel washed out during periods of high flow.

Because of the high risk of producing only short-term benefits or even negative effects, spawning habitat creation as a mitigation or enhancement technique has limited application and should be done only with a clear understanding of the physical processes involved and the biological needs of the fish. True restoration of salmonid spawning habitat requires reestablishment of the physical processes surrounding the natural creation and maintenance of spawning habitat. A process-oriented approach encourages natural habitat diversity and has the potential to not only produce long-lasting, high quality salmonid spawning habitat, but to benefit other fish and wildlife species and age classes as well.

Techniques to consider include:

- Stopping or curtailing operation of equipment and vehicles within a stream channel, yarding of logs through a channel, and foot traffic by livestock, people and pets, that take place at or near spawning beds
- Increasing Spawning Gravel Availability—
    - Restore natural gravel supply that has been lost (see Restoring Sediment Supply)
    - Encourage gravel stability
        - Restore natural levels of stream discharge (see Restoring Stream Hydrology)
        - Restore stream access to its floodplain to reduce water velocity during high flows (see *Channel Construction and Modification*, *Levee Removal and*

Setback techniques)

- Restore natural spawning gravel deposition and maintenance pattern. Channel morphology and the presence of obstructions to flow (such as bedrock outcrops, boulders, and large woody material) provide locations where spawning gravels are deposited (Schuett-Hames and Pleus 1996).
    - Restore natural channel morphology (see *Channel Construction and Modification* technique)
    - Restore natural obstructions to flow (see *Structures to Create and Maintain Natural Channel Bedform and Habitat Diversity, Replenish Woody Debris, Debris Jams, Boulders* techniques)
- Restore natural channel pattern, profile, and cross-section that is in balance with its discharge and sediment load (see *Channel Construction and Modification, Levee Removal and Setback* techniques).

o Increase available spawning area

- Increase length of stream by restoring natural planform to a channelized stream (see *Channel Construction and Modification* technique)
- Restore access of spawning fish to spawning habitat that has become isolated from the main stream (see Restoring Habitat Connectivity)
- Remove structures that create artificial surfaces unsuitable for spawning (e.g., culverts, concrete liners)
- Construct spawning side channel (see *Side Channel* technique)
- Restore natural levels of stream discharge. Streamflow at the time of spawning determines the available amount of submerged spawning habitat, the ability of fish to access spawning grounds, and the water depth and velocity over the spawning bed. (see Restoring Stream Hydrology)

- Improving the Quality of Spawning Gravel
    - Reduce excessive supply of fines (see *Sediment Control* technique)
    - Encouraging Gravel Sorting and Cleaning—
        - Restore in-stream roughness elements to the channel such as in-stream structures (including large woody material). Structures form obstructions to flow causing local scour pools to form. The velocity gradient around and downstream of the obstruction forms pool tailouts comprised of naturally sorted material. (see *Structures to Create and Maintain Natural Channel Bedform and Habitat Diversity, Replenish Woody Debris, Debris Jams, Boulders* techniques)
        - Restore natural channel pattern and profile to a channelized stream. In low gradient channels with pool/riffle morphology, velocity differences between pools and riffles during peak flows result in sorting of sediments and deposition of coarse gravel in bars and riffles (Keller 1971). (See *Channel Construction and Modification* technique)

        - Artificially clean gravel (e.g., Gravel Gertie) (see *Spawning Gravel* technique). This technique will only provide short-term benefits to affected reach, if any, without repeated maintenance. The detriment to stream habitat caused by this technique may outweigh any benefit.
- Eliminating and/or Reducing Unnatural Channel Aggradation—
    - Reduce any excessive supply of sediment to the stream (see Restoring Sediment Supply)
    - Increase sediment transport capacity of the channel
        - Restore natural stream hydrology (see Restoring Stream Hydrology)
        - Restore natural channel pattern, profile, and cross-section that is in balance with its discharge and sediment load (see *Channel Construction and Modification* technique)
        - Restore natural channel location to prevent artificially perched conditions (see *Channel Construction and Modification* technique)
        - Reduce or eliminate the presence of in-stream reed canary grass (see *Riparian Management* technique)
        - Remove artificial structures, such as dams and road crossings, that have caused large-scale backwater, reducing sediment transport.
        - Restore structures in the reach to maintain the channel thalweg through creation of a relatively stable pattern of pools and bars. (see *Structures to Create and Maintain Natural Channel Bedform and Habitat Diversity* technique)
- Improving Water Quality (see Restoring Water Quality)
- Providing Adequate Water Depth and Velocity (see *Channel Construction and Modification* technique and Restoring Stream Hydrology)
- Increasing Cover (see Restoring Habitat Diversity)

4.4.10 Restoring Salmonid Rearing Habitat --- **Not Available at This Time**

4.4.11 *Tips on Deciding Whether or Not to Work Directly in Stream Channel When Planning and Designing a Stream Restoration Project* --- ***To Be Modified and Moved to 4.3.7 (Risk Assessment)***

Deciding whether or not to conduct in-stream restoration work can be very difficult because of the number of variables that need to be considered. Following is a brief summary of issues to be considered when making that decision. This protocol was developed by Janine Castro, US Fish and Wildlife Service, and Rob Sampson, Natural Resources Conservation Service as draft guidance.

1. **Channel Slope**

a. >20% -- do not work in the stream.
b. 3 -- 20% -- RED FLAG -- generally avoid working in these streams, but there are exceptions for streams less than 8%.
c. <3% -- these streams are within a reasonable range for in-stream work.
d. <0.1 % -- These streams typically have large secondary currents. There may be significant annual vertical adjustments (rather than lateral). Any hard structures are vulnerable to collapse due to the temporal variability in bed elevation.

2. **Bedload**
   a. Bedrock -- use caution because these are typically high-energy systems with minimal boundary roughness to reduce velocities. Shear stress in the near bank region can be extreme.
   b. Boulder -- do not work in these stream channels if the flows are moving boulder size material. If the boulders are a result of a landslide or other type of mass movement, then project work may be appropriate.
   c. Cobble -- generally acceptable risk for stream projects, although abrasion of structures can be of concern.
   d. Gravel -- stream projects involving rock and wood structures are appropriate in these stream types.
   e. Sand -- stream projects are acceptable in sand bed streams; however, rock structures may fail if there is not a hard substratum below the sandy bed. Wood structures are often more appropriate in sand bed streams. These are very erodible channels -- appropriate filters are essential.
   f. Silt/Clay -- same cautions as sand bed streams, although silt/clay streams may have extremely resistant channel boundaries and function much like a bedrock channel.

NOTE: Be extremely cautious if the channel is composed of fine grain material and has a low floodprone width (<180%, see below).

3. **Landscape Position** -- Avoid areas in the landscape that are naturally "unstable" such as alluvial fans, delta fans, and actively eroding source areas. The goal is to restore natural channel stability, not create stability where there is none naturally.

4. **Extent of Floodprone Width**
   a. Floodprone width is less than 140% of the bankfull channel width -- do not work in these streams unless more floodprone area can be created or obtained (i.e. removing or setting back a dike).
   b. Floodprone width is between 140 and 220% of the bankfull channel width -- use caution in these stream types; there may be excessive stress on the stream banks. Try to gain more floodplain if appropriate. or use energy dissipaters in the stream to reduce shear stress and high velocities.

c. Floodprone width is greater than 220% of the bankfull channel width -- it is appropriate to work in these stream types.

NOTE: Floodprone width is defined as the width of the floodplain at an elevation that is 2 times the maximum bankfull depth (Rosgen 1996).

5. **Shape of the Hydrograph** –A hydrograph is a graphical depiction of stream discharge over time. Each watershed will respond differently to precipitation events; its response is a function of watershed and stream channel characteristics such as slope, shape, size, and channel conveyance. If the stream hydrograph has a very steep rising limb (meaning that the magnitude of the flood peak is high and/or the time it takes for stream discharge to reach its peak is low relative to other streams), then in-stream restoration or stabilization work will be more difficult. Initial restoration projects should focus in areas where the hydrograph is smoother with a more gentle rising limb.

An example of a typical watershed with a steep rising limb hydrograph is an urban channel. Urban channels typically have a high percentage of impervious surface in their watersheds providing less retention of water during storm events and more rapid runoff to the stream than a similarly sized and shaped forested watershed.

6. **Vertical stability** -- if the stream channel is aggrading or degrading, then measures to stop or slow this process (if appropriate) must be initially addressed. If it is not possible to change the vertical stability, or if it is an entirely natural process, then it is not recommended that an in-stream project occur at the site.

7. **Landowner cooperation** -- any in-stream or streambank project requires compatible land use practices and an appropriate riparian buffer. If the landowner is unwilling to cooperate to provide additional protection for his/her land, then the project should be reconsidered. It is a disservice to the landowner to install a project without the appropriate riparian buffer, because the riparian buffer provides long-term protection, while a structure provides short-term protection. Stream restoration should consider and include the active stream channel, riparian corridor, and associated floodplain.

8. **Location of Infrastructure** -- this basically covers risk analysis. If the project is just upstream of a bridge, caution should be used, both in agreeing to do the project, and in the type of technique employed. The potential to affect adjacent landowners should also be addressed. Areas with available floodplain and little infrastructure are the best places to try new practices.

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